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DEPARTMENT OF BIOLOGICAL SCIENCES
FLORIDA TECHNOLOGICAL UNIVERSITY
ORLANDO, FLORIDA 32816

WIND AND THE WINTER-EXPOSED PLANT. In his paper "Snow Cover and the *Diapensia lapponica* habitat in the White Mountains, New Hampshire" (Rhodora 74: 358-377), W. N. Tiffney, Jr. makes repeated reference to the prevalence of high winds in the alpine zone which, in his belief, ". . . promote desiccation in winter-exposed plants". The idea that winter desiccation is significantly influenced by high winds is shared by at least one other ecologist (Lindsay, 1971), but this conclusion seems to be based on the application of summertime wind effects to the wintertime situation. The energy budget of the winter-exposed plant is, however, quite different from that of the more freely transpiring plant in a summer microclimate, and the prevalence of high winter winds may instead forestall damaging water loss.

Transpiration from a leaf surface, at any time, is directly proportional to the water vapor concentration gradient between the leaf and air, and is inversely proportional to the diffusive resistances offered by the leaf and boundary layer of air adjacent to the leaf (Gates, 1965). Hence $T = \frac{c_l - c_a}{r_l + r_a}$ where T is the transpiration rate, $c_l - c_a$ is the water vapor concentration difference between the intercellular spaces of the leaf and the bulk air outside the leaf boundary layer, and r_l and r_a are respectively the leaf and boundary resistance to gaseous transfer. It should be noted that the driving force for transpiration, $c_l - c_a$, is strongly influenced by the temperature difference between the leaf and air, since saturation vapor pressure is a function of temperature. The greater the elevation of leaf temperature above air temperature, the greater the vapor concentration gradient between the leaf and air.

Leaf resistances to the diffusion of water vapor are provided by the stomates and cuticle, the relative magnitude of these being somewhat species dependent. The minimum stomatal resistance of the alpine species *Ledum groenlandicum* is for, example, less than 2 sec cm^{-1}, as determined for plants growing in both a northern bog (Small, 1972) and above timberline on Mt. Washington, New Hampshire (Marchand, unpublished data). The stomatal resistance of conifers may be somewhat higher, perhaps near 20 sec cm^{-1} (Waggoner and Turner, 1971). In contrast, cuticular resistance is usually several times greater in magnitude, having been reported (Holmgren et al., 1965) as high as 460 sec cm^{-1} for the European species *Quercus robur*. In addition, cuticular resistance has been found to increase sharply with decreasing temperature (Holmgren et al., 1965).

Boundary layer resistance is provided by a transfer zone of air in contact with (and influenced by) the leaf. The thinner this surrounding layer, the more rapid will be the heat convection or vapor transfer through this zone, since heat and vapor concentration gradients between the leaf and bulk air will be steeper. Single leaf boundary layer resistances have been found to be generally less than 0.9 sec cm^{-1} for several deciduous woodland species (Holmgren et al., 1965), although this will vary directly with leaf size and shape and inversely with windspeed (Gates, 1965).

It is through reduction of boundary layer resistance that the influence of wind currents is important. The effect of wind is two-fold; (1) it facilitates removal of moist air from the leaf surface, thereby increasing the rate of transpiration, and (2) it increases the rate of heat transfer from the leaf, through forced convection, thus tending to maintain temperature equilibrium between the leaf and air. In the latter case, $c_l - c_a$ is reduced and consequently transpiration is decreased. The relative importance of these two processes will depend on other microenvironmental factors as well as on the physiological behavior of the plant.

During the summer growth period, the most significant leaf resistance to loss of water (under non-stress conditions) is that of the open stomates. Cuticular transpiration is negligible as long as the stomates remain open. At this time of year then, the boundary layer resistance is closer in magnitude to the leaf resistance and any reduction of r_a by turbulent exchange becomes significant in terms of increasing transpiration. Under these circumstances, the effect of wind on leaf temperature seems to be of minor importance.

In the wintertime, the relative importance of the diffusive resistances is changed significantly. Stomatal opening has not been reported to occur during the winter (Tranquillini, 1964; Schulze et al., 1967) as apparently it is prevented by low temperatures (Staefelt, 1962). As a result, vapor diffusion is largely via cuticular pathways and the leaf resistance thus becomes very high.* It is on this point that my argument is based. As seen from the above transpiration model, when r_l is high, r_a becomes negligible and any reduction of the boundary layer resistance by high winds is unimportant in terms of increasing vapor transfer. So the dominant effect of wind in the wintertime is, in my opinion, related to the consequences of forced convection, and these are (1) maintenance of leaf temperatures below the freezing point of cell water when air temperatures are very low, and (2) reduction of temperature differences between the leaf and air with consequent reduction of $c_l - c_a$. In the first case, water loss will be limited to the process of sublimation from frozen tissues, requiring greater energy input than for the evaporation of free water. In both cases, the net effect of wind would be to reduce, rather than increase water loss.

Where reference has been made to the work of Tranquillini (1964) and Sakai (1970), citing conditions of winter drought and desiccation damage in alpine areas, it should

*The discussion here is pertinent only to evergreen species, and since heavy cutinization is characteristic of evergreens, the value of cuticular resistance is assumed to be very high relative to r_a.

be noted that such conditions are the combined result of frozen soils and the strong heating of plant parts above freezing, due to high direct and reflected radiation load on exposed plants. Thus it is most likely that winter-exposed plants will experience damaging water loss on days which are clear and windless. Whether or not winter desiccation in the alpine areas of the White Mts. of New Hampshire can be substantiated, the conclusion that ". . . low temperatures and high winds combine to promote severe desiccation in this snow-free area" seems unwarranted on the basis of simple physical considerations.

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PETER J. MARCHAND
DEPARTMENT OF BOTANY
UNIVERSITY OF NEW HAMPSHIRE
DURHAM 03824